MANAGEMENT OF COMMON STORAGE HOUSES FOR APPLES IN THE PACIFIC NORTHWEST

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AS THE production of apples in the Pacific Northwest has increased rapidly in recent years, the growers have come more and more to realize the economic necessity of increased storage facilities in the producing sections. As only a part of the crop can be shipped during the harvesting and packing season, and as cold storage is available for but a small proportion of the apples, a considerable quantity must be cared for in warehouses or in common storage houses for periods varying from a few weeks to a few months. For several years the quality and condition of the apples when removed from common storage have been disappointing.

Careful investigations during several seasons have shown that the unsatisfactory results generally have been due to the improper construction of the storage houses and their indifferent management. They also demonstrate that with a few minor changes and better management most of the storage houses can be made to give fairly satisfactory results.

This bulletin deals with the fundamentals of construction and the efficient management of common storage houses for apples under the conditions prevailing in Washington, Oregon, Idaho, and Montana.

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COMMON OR AIR-COOLED STORAGE HOUSES.

THE term "common or air-cooled storage" is used to designate that method of storage which utilizes the natural atmospheric temperatures for cooling. It differs essentially from cold storage only in the method by which the fruit is cooled and maintained at storage temperatures. In common storage, ventilation with the outside air is relied upon to cool the contents of the storage building. In cold storage, the cooling is effected by the use of ice or some means of artificial refrigeration. Because of the fact that the cooling is accomplished by the circulation of outside air, common storage houses are frequently spoken of as air cooled.

PRACTICABILITY OF COMMON STORAGE.

In certain sections of the country where the climatic conditions are favorable, apples can be held in common storage for long periods of

[1] The studies upon which this bulletin is based were made in the Fruit Handling and Storage Investigations of the Office of Horticultural and Pomological Investigations of the Bureau of Plant Industry. The fruit and vegetable handling, transportation, and storage investigations of the department are now prosecuted jointly and cooperatively by the Bureau of Plant Industry and the Office of Markets and Rural Organization.

time in almost as good condition as in cold storage. In such sections common storage is utilized to a considerable extent for the storage of winter apples. Moreover, in some of the more northern apple sections common storage has long been the main reliance for the storage of winter apples, largely on account of its convenience and much lower cost. In many apple-producing sections there is not sufficient cold-storage space to care properly for the entire crop, and common storage is therefore employed for a considerable part of it.

Common storage can be used as a valuable supplement to cold storage; but when long storage periods are necessary, cold storage possesses advantages over common storage. Where common storage is so employed, it should be the aim to move that portion of the crop held in common storage earlier in the season than that held in cold storage.

UTILIZATION OF COMMON STORAGE IN THE PACIFIC NORTHWEST.

In the apple-producing sections of the Northwest little use was made of common storage until the last few seasons. During recent years there has been an enormous increase in the acreage planted to apples. As this acreage began to come into bearing it became evident that the cold-storage facilities were entirely inadequate to care for that part of the crop which must necessarily be held over for storage at the producing end. More and more, therefore, dependence has been placed on common storage, and a number of such storage houses have recently been constructed in Oregon, Washington, Idaho, and Montana. These storage houses are built either entirely above ground or with half basements. Some of them are practically only ordinary packing warehouses, while others have been constructed with insulation fully comparable to that used in cold storage warehouses. The results as related to the keeping quality of the apples stored necessarily vary both with the efficiency of the insulation and with the management. In some houses apples have been held in common storage until spring in remarkably good condition, while in others the results have been disappointing.

EFFICIENT MANAGEMENT AND IMPROVED CONSTRUCTION NEEDED.

The fact that apples have been held in good condition for several months in common storage in the Pacific Northwest shows that this method of storage is entirely practicable, at least in some sections. The numerous instances of failure to hold apples in common storage in good condition for a reasonable period are indicative of serious faults both in construction and management, and careful investigation of these houses has conclusively shown that marked improvement is needed. In many cases accurate information has been lacking regarding the fundamental factors that govern the condition of

apples in common storage. Often the houses are neither properly constructed nor adequately insulated.

The most common cause of failure, however, is not so much faulty construction as it is bad management of these houses, especially at the beginning of the storage season. The careless handling of the fruit and faulty operation of the common storage houses are chiefly to blame for the poor keeping quality of a considerable portion of the apples in common storage during some seasons. Lack of information regarding the fundamental principles of common storage and the failure to utilize the common storage houses to the best advantage are responsible for serious financial losses to the growers and to the industry generally. It is not the purpose of this bulletin to discuss in detail the best or most economical methods of constructing common storage houses, but rather to point out how the houses already built can be utilized to the best advantage through careful and intelligent management.

FACTORS GOVERNING THE KEEPING QUALITY OF APPLES IN STORAGE.

In order that the growers and the managers of common storage houses may handle the crop and the houses to the best advantage it is essential that they have accurate information regarding the fundamental factors that govern the condition of apples in either common or cold storage. The most important factors which determine the condition of apples in storage are (1) the inherent keeping quality of the variety, (2) the soil conditions and the cultivation of the trees, (3) the care exercised in the harvesting, (4) the maturity of the fruit at the time of picking, (5) the promptness in cooling the apples, and (6) the temperatures and humidity conditions in the storage houses in which they are held.

VARIETY.

Of first importance in determining the storage life of apples in either cold or common storage is the variety. Varieties differ very greatly as regards inherent keeping quality and consequently the length of time in which they can be held in good condition in storage. Nearly everyone is familiar in a general way with the comparative keeping qualities of the principal commercial varieties of apples. It is exceedingly important from the standpoint of successful storage that the different varieties be held in storage for only such periods as general experience with them justifies. Due weight should be given to the fact that the different varieties can be successfully held for longer periods in cold than in common storage; also to the fact that after removal from storage the apples must be in transit a considerable time before reaching market, and possibly as long again before reaching the consumer.

CULTURE.

Cultural factors, including location, type of soil, age of trees, cultural methods, irrigation, and spraying practices, are all of vital importance. Upon these depend more or less the inherent storage or keeping quality of the fruit and its freedom from blemishes and fungous diseases when ready for harvesting. The lack of sanitation and of proper practices in spraying oftentimes results in heavy losses to the grower on account of the development of diseases, like scab and anthracnose, in either cold or common storage. These factors, too, determine largely the quality and appearance of the product, its suitability for storage, and its relative market value.

CARE IN HANDLING.

Nearly all growers realize that care in handling is necessary for the best results. Many, however, through ignorance or because of carelessness or indifference, subject their fruit to early decay and spoilage through needless rough handling in harvesting. A great deal of rough handling is due to lack of knowledge of what constitutes careful handling. It is not realized that it is necessary to preserve the skin of the fruit in a sound, unbroken condition. Much of the decay occurring in storage is caused by blue mold, a fungus which, as a rule, does not gain entrance into the flesh of the fruit except through injuries of the skin. Keeping in mind the fact that blue mold is a very serious storage trouble of apples, the importance of the most careful handling from tree to car or storage is clearly apparent. Preserving the skin of the fruit in a sound, unbroken, unbruised condition is therefore one of the simplest and surest ways of avoiding blue-mold injury either in transit or storage. Every precaution should be taken to handle the fruit with the utmost care from the tree to the storage house, in order to have only sound, uninjured fruit go into storage. The bruising of the fruit in any of the operations of handling means inevitable decay in either common or cold storage. The sound, merchantable condition of any perishable fruit depends upon the prevention of mechanical injuries more than on any other factor. Rapid deterioration takes place when the fruit is allowed to stand in the orchard after it is harvested or in the packing house for days or weeks before being transferred to the storage house.

MATURITY OF FRUIT.

Another factor of great importance in connection with the keeping quality of apples is the stage of maturity at which the fruit is picked. No other single factor has such an important bearing on the development of scald in storage. Apples picked too green will almost invariably develop a great deal more scald in storage than fruit from the same trees picked at the proper stage of maturity.

Scald is one of the most serious troubles in either cold or common storage and greatly reduces the value of the fruit for market purposes.

No other factor is more difficult to determine accurately than the proper stage of maturity at which apples should be picked for storage. As no definite rules can be laid down, each grower will have to study his own fruit and conditions. The color of the seeds and the blush or red color of the variety are in some measure indications of proper maturity. They are not dependable guides, however, as a rule. In general, the one factor of greatest dependability is the ground color of the variety. The ground color, which is green before the apple begins to mature, gradually lightens, whitens, and yellows. Usually, the green should be replaced by a lighter color or slight yellow before the apple can be considered of proper maturity for picking and storage purposes. It should be borne in mind, however, that allowance must necessarily be made for differences in the natural color of varieties, for exposure to sunlight, etc. Only experience will enable the grower to give proper weight to the various factors involved.

Good judgment also must be exercised, so as not to permit the apples to become overripe. Overripeness is fully as serious, if not more serious, than immaturity. Overripe fruit is much nearer the end of its life limit and consequently will go down with even greater rapidity in storage than immature fruit. All the fruit on the tree is never in the same stage of ripeness at one time. Some varieties have so long a ripening season that two or three pickings are necessary to insure a fair degree of uniformity of ripeness. When so picked, fruit of better keeping quality can be secured in the case of such varieties than by a single picking. Some varieties, on the other hand, ripen their entire crop so nearly at one time that the slight advantage gained by several pickings does not justify the increased cost. This is conspicuously the case where the trees are not overloaded.

PROMPTNESS OF COOLING.

The apple, like all fruits, is a living organism, and its life cycle, which begins in the blossom, ends under natural conditions in the death decay of the fruit. When the fruit is picked from the tree its life processes do not stop. On the contrary, at ordinary temperatures they apparently advance more rapidly than before. These ripening processes, however, may be retarded effectively by low temperatures. In general, the quicker the cooling and the lower the temperature at which the fruit is held, provided it is not below freezing, the more effectively are these life processes retarded and the longer the period during which the fruit can be kept in good, sound condi-

tion. Prompt cooling is essential, therefore, in order effectively to retard the ripening processes that result finally in death decay.

Another object of quick cooling is to prevent the germination of fungous spores and to retard the development of fungous organisms which attack and cause the decay of fruit in storage. Quick cooling also tends to prevent the development of skin blemishes, such as scald, soft scald, and Jonathan spot, which depreciate the fruit's appearance and market value. Extensive experimental work has demonstrated conclusively that prompt cooling is of prime importance in increasing the length of time that fruit can be held in storage in good condition. With slow cooling and irregular temperature conditions there is a marked deterioration in the natural flavor of the apple, which seriously impairs the dessert quality of much of the fruit held in common storage. A comparison of two lots of the same fruit from cold storage and common storage often shows a marked inferiority of flavor in the common-storage fruit.

Prompt cooling and the maintenance of uniform conditions of temperature and humidity in common storage houses are important factors in preserving the natural flavor, aroma, and attractive appearance of apples throughout the normal storage season. Fruit held in high temperatures for any considerable period after harvesting soon becomes overripe and may lose several weeks or months of its normal storage life. It should be kept in mind that fruit allowed to become overripe, either on the trees or after harvesting, can never regain in storage the quality and vitality it once possessed. Fruit allowed to stand in the orchard in the sun will not keep as long or as well as that promptly placed in the shade and cooled by remaining out over night in open field boxes. Fruit placed in an assorting, grading, or common storage room that is warm rapidly loses its keeping qualities. Disregard of these simple, yet vitally important, matters causes heavy annual losses.

STORAGE TEMPERATURES.

No temperature which will not seriously damage the fruit by freezing will entirely check the ripening processes or the growth of fungi which cause decay. The most effective storage temperature for most apples is one between 31° and 32° F. Needless to say, without the provision of artificial refrigeration it is neither possible to reduce the temperature of the fruit to this point quickly nor ordinarily to maintain this temperature uniformly. In fact, it is seldom possible to reduce the temperature of the fruit in common storage at any time to 32° F. in most northwestern sections. Even though ideal conditions can not usually be obtained in common storage, the length of time that apples can be held in good condition will depend largely on how nearly this ideal temperature can be realized.

PROPER HUMIDITY CONDITIONS IN STORAGE.

The maintenance of the proper humidity is perhaps as important as the maintenance of proper temperature conditions and is fortunately less difficult. During the early part of the season, when the air is constantly being changed by ventilation and the circulation of cold air through the house, the humidity factor largely takes care of itself. In houses using a half basement for storage, the floor is frequently not boarded or cemented over, and the moisture given off by the soil or earth serves to maintain fairly satisfactory humidity conditions. In such cases a slatted false floor should be put in, to carry the load and to keep the fruit from contact with the soil. While earthen floors have given fairly good satisfaction, it is not because such floors make it easier to maintain the desired temperature conditions, but because they serve to supply the necessary humidity and moisture; in fact, they may make the maintenance of low-temperature conditions somewhat more difficult, owing to the conduction of heat through the earth into the storage room. Where such floors are not used, the proper moisture conditions may be maintained by sprinkling the floor liberally with water at frequent intervals. It is impossible to state definitely what degree of humidity is most favorable for the storage of apples, as no satisfactory or entirely reliable determinations have been made. There should be sufficient moisture, however, to prevent shriveling or wilting, yet not so much as to cause the excessive growth of fungous organisms.

THE GROWER'S RESPONSIBILITY FOR THE KEEPING QUALITY OF FRUIT.

Since cultural and handling methods largely determine the condition of fruit when it is stored, the first responsibility for its successful storage rests on the grower. The three factors of culture, care in harvesting, and the maturity of the apples are all of exceedingly great importance in determining the length of time that fruit can be held in good condition in either common or cold storage. These are all factors, as has already been mentioned, for which the grower himself is primarily responsible. To the extent that these govern keeping quality, he is responsible for the conditions in storage. Prompt cooling or the maintenance of proper temperature conditions can not restore lost quality due to overripeness, carelessness in handling, or wrong cultural practices. In order to secure the best results all three factors, good culture, proper maturity, and careful harvesting, must go hand in hand. No one can make up for any other, and carelessness or neglect in one may nullify all the good accomplished by care in the other two.

THE STORAGE-HOUSE MANAGER'S RESPONSIBILITY FOR THE KEEPING QUALITY OF FRUIT.

Properly grown, matured, and handled fruit can not be held in good condition for the maximum length of time in storage unless it is cooled with some degree of promptness. Neither can it be stored for the maximum length of time unless it is held under favorable storage temperatures and conditions. The two factors of promptness of cooling and the maintenance of proper storage temperatures are inseparably associated with both the construction and the management of air-cooled storage houses. These are the two factors for which the manager of the storage house is primarily responsible. If the grower is also the manager of his own common storage house, full responsibility for the condition of the fruit in storage must necessarily devolve on him. If, however, the common storage house is managed by an association or by some one other than the grower, the responsibility for the keeping quality rests both with the grower and the storage-house manager. When the apples are grown, harvested, and stored by a single individual, there is no question as to who is responsible for every act that tends to prolong or shorten the life of the fruit. If, however, there is a division of labor, one man growing and harvesting and another storing the fruit, then there is always a question as to what may have caused the loss in storage and who was responsible for it.

Inefficient management of storage houses results usually in the very slow cooling of the fruit and the maintenance of temperatures anything but desirable. All the money invested in the orchard enterprise and all the care exercised in growing and harvesting the crop may be wholly wasted by inattention to the details of proper storage-house management. It is therefore evident that if air-cooled storage houses are to be successfully employed it is essential that proper attention be given to both construction and management, in order to preserve the keeping quality that the fruit possesses at the time it is placed in storage.

THE EFFICIENCY OF COMMON STORAGE DEPENDENT ON VENTILATION AND INSULATION.

The efficiency of a common storage house will depend primarily upon the rapidity which the fruit is cooled and the storage temperatures maintained. A common storage building, therefore, must necessarily provide for two things—the freest circulation and intake of cold air during the night or the cooler periods of the day and the conservation of this cold air by closing all hatches and intakes before the outside temperature begins to rise and by preventing the leakage of heat through the walls, floors, and ceilings of the build-

ing. For the intake of cold air, openings should be provided at or near the ground or the lower part of the building, while air shafts leading upward from the ceiling of the storage chamber or chambers should be provided to carry off the warm air. To prevent the leakage of heat into the building, the walls, ceilings, and floors must be insulated. As these two factors govern to a considerable extent the rapidity of cooling and the maintenance of low temperatures, the importance of ventilation and insulation can hardly be overestimated. No other two factors of construction or operation are of greater importance. Upon these depend in the final analysis the success or failure of the common storage house.

THE VENTILATION OF A COMMON STORAGE HOUSE.

HOW VENTILATION IS SECURED.

The circulation of air in a common storage house is usually secured through natural ventilation induced by the difference in the weight of air at different temperatures. Air when warm expands and occupies a greater amount of space than when cold. The weight of a cubic foot of warm air is less than the weight of a cubic foot of cold air. When the air inside of the building is warmer than that outside, the cold outside air, by reason of its greater weight, flows in through the openings at the lower part of the building, as illustrated in figure 1. This incoming colder air pushes out the warmer and lighter air through the vents and air shafts at the ceiling.

This action is almost exactly the same as in an ordinary chimney, the only difference being that the air in the ventilating flue is not nearly as warm as that in the chimney; therefore, the tendency to produce a draft in the flue is very much less than in a chimney of equal height. The difference in air pressure induced by the difference in air temperature is so slight that circulation is easily checked if the air passages are small or crooked. To obtain free, abundant circulation it is necessary that the air openings be of liberal size, that the air shafts be straight and direct, and that these shafts extend through the roof to a considerable height above it.

NECESSITY FOR FREE AND ABUNDANT AIR CIRCULATION.

To cool a large mass of warm fruit in a storage house requires the circulation of very large volumes of air. To cool the fruit at all quickly the air must either be very cold or the circulation must be very rapid. Warm fruit in closed boxes or barrels will stand a current of air at freezing temperatures for several hours without damage by freezing. The cooling of boxed or barreled fruit by a gentle current of moderately cold air is therefore necessarily extremely slow. The temperature of the fruit, even near the outside of the package, changes but slowly. Farther inside the package there may be no

appreciable cooling until the outside fruit is materially cooled. Likewise, packages within large compact stacks of fruit will not commence to cool to any extent until the outside packages have been reduced considerably in temperature.

The slowness with which the fruit is cooled, even under the best of conditions, emphasizes strongly the need of both the free and the rapid circulation of cold air. The necessity for free, unobstructed circulation is further increased in the early autumn, when the coolest outdoor temperatures are moderately warm. In order to accomplish any appreciable cooling at such times, large volumes of air must be circulated through the fruit. Quick, prompt cooling may add weeks, even months, to the period during which apples can be held in good condition. The relatively short time during which apples can be kept in good condition in some storage houses is caused very largely by delayed cooling and by the storage of fruit at temperatures that are too high.

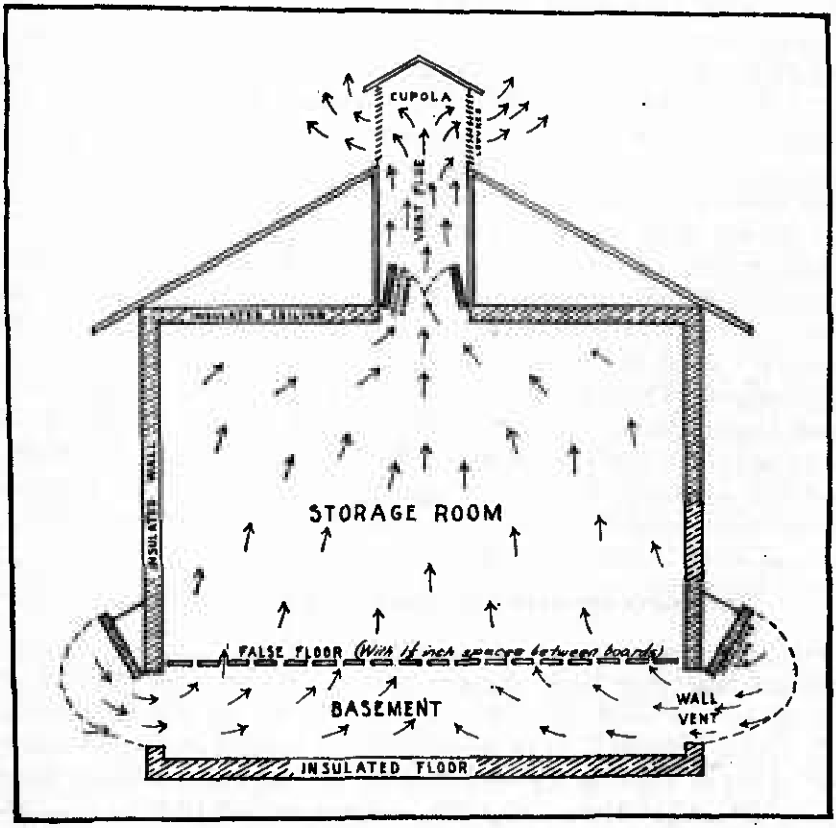

FIG. 1.—Cross section of a common storage house, with vent doors and dampers open, showing how air circulates when the temperature of the air outside the house is lower than the temperature of the product stored in the storage room.

RATE OF COOLING BY NATURAL CIRCULATION.

The rate of cooling of fruit in an air temperature of 32° F. is none too fast, especially in the center of a package or in packages within a stack of fruit not properly spaced. It is not uncommon to find overripe, badly decayed apples in the center of a barrel held at regulation cold-storage temperatures. This overripeness is due mainly to the slow cooling of the fruit in the center of the barrel. If overripeness and deterioration caused by slow cooling occur in cold storage houses, it is not to be wondered at that stock frequently shows overripeness and bad condition at the end of only one or two months in common storage.

The difference in the weight of air due to differences of temperature is so slight that natural circulation is, at the best, slow. If, as frequently happens during the autumn or early part of the season, the outside temperature does not go below 45° or 50° F., the rate of cooling will be exceedingly slow. Not only are the lowest temperatures that are possible under such conditions relatively high, but the circulation of the air is correspondingly slow. The amount of heat that slowly circulated air at relatively high temperatures removes from the fruit in a given time is very small. Even with the outside temperatures near freezing, weeks and months may be required to reduce by natural circulation all the fruit in tight containers in large stacks to the desired storage temperature.

SIZE AND ARRANGEMENT OF VENTILATORS.

To cool the fruit with a reasonable degree of rapidity, the air circulation must be free and abundant. Openings a few inches in diameter are entirely inadequate to provide the necessary air circulation. Few houses have either a sufficient number of openings or openings of sufficient size to be effective. Openings a few inches in diameter, such as are very often provided, may be adequate during the winter after the fruit has been thoroughly cooled and when the outside temperatures are much colder than in early autumn. It is during the first part of the storage season, however, when the coldest outside temperatures are rather high and it is difficult to secure effective cooling, that the critical period, both in the life of the fruit and in the management of the storage house, occurs. The openings, therefore, must be of a size to permit the free, abundant, and rapid circulation of air.

Unfortunately, there are few accurate data on the size and number of ventilators necessary to cool most effectively and quickly a house of a given size with air of a given temperature. The rate of cooling will naturally depend on the outdoor temperature, the size of the house, the quantity of fruit in it, and the temperature of the apples when stored. The limited data at hand and practical experience

emphasize strongly the need of large openings to effect a free and abundant circulation. The openings for the intake of cold air should be at least 24 by 18 inches. One such opening should be provided for every 10 feet in length, as well as width, on each side and end of the house. These openings should be opposite and so arranged that the alleys or spaces between the stacks of fruit in the storage room will come opposite the openings. The illustration on the title-page shows a storage house provided with a sufficient number of ventilator openings of approximately proper size. This house is also provided with a false or slatted floor even with the tops of these openings to facilitate the rapid and effective cooling of stored fruit. The shutters or doors, raised in this illustration but closed in figure 2, are several inches in thickness, well padded, and so constructed as to provide insulation when closed equal to that in the walls.

OPERATION OF VENTILATORS.

As previously explained, the movement of air is brought about by the difference in weight of the warm and the cold air. Whenever, therefore, the interior of the building is warmer than the outside air, the cold air will flow in through the lower ventilators if these are left open. (See fig. 1.) The warmer air in the house passing out through the upper ventilators will be replaced by an equal volume of colder air flowing in through the openings at the base of

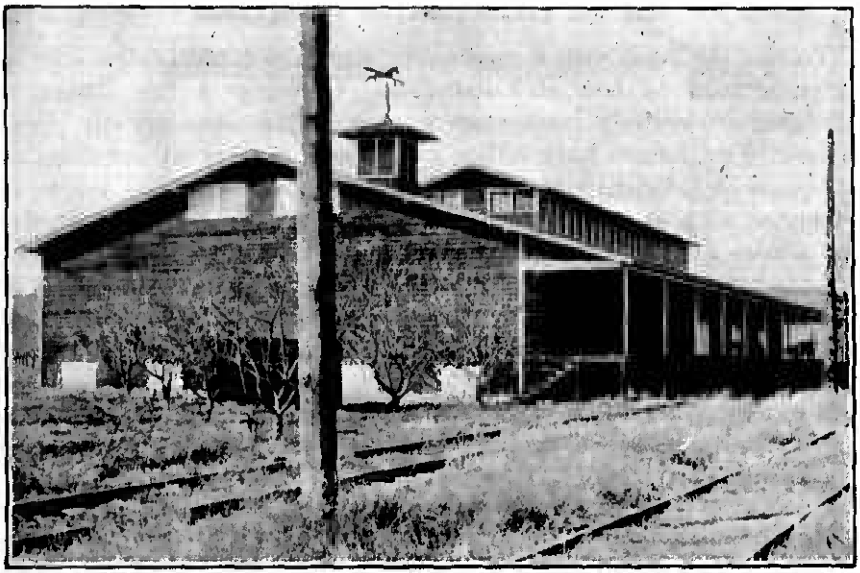

FIG. 2.—A very successful type of common storage house for apples, with ventilators closed. The packing house occupies the farther end of the building. Another view of the same storage house, with ventilators open, appears on the title-page, attention being called to the number, size, and arrangement of the ventilators.

the building. It is therefore necessary that the temperatures, both inside and outside, be watched carefully and advantage taken of every opportunity to open the house when the air outside is colder than that inside. Air currents through the intake and discharge vents are quickly reversed as soon as the relation of the inside and outside temperatures is changed, as illustrated in figure 3. As soon, therefore, as the air outside becomes warmer than that inside the storage house all ventilators should be tightly closed and kept closed.

During the first part of the packing season it is not an uncommon practice to leave the ventilators open all day as well as all night. This practice is contrary to the very principle of cooling by ventilation. If these openings or ventilators are not closed and opened in conformance with actual inside and outside temperatures, they are of no use, and the fruit might as well, or better, be stored in open warehouses. If the vents are left open during the heat of the day, not only will there be a loss of the beneficial effect of the cooling

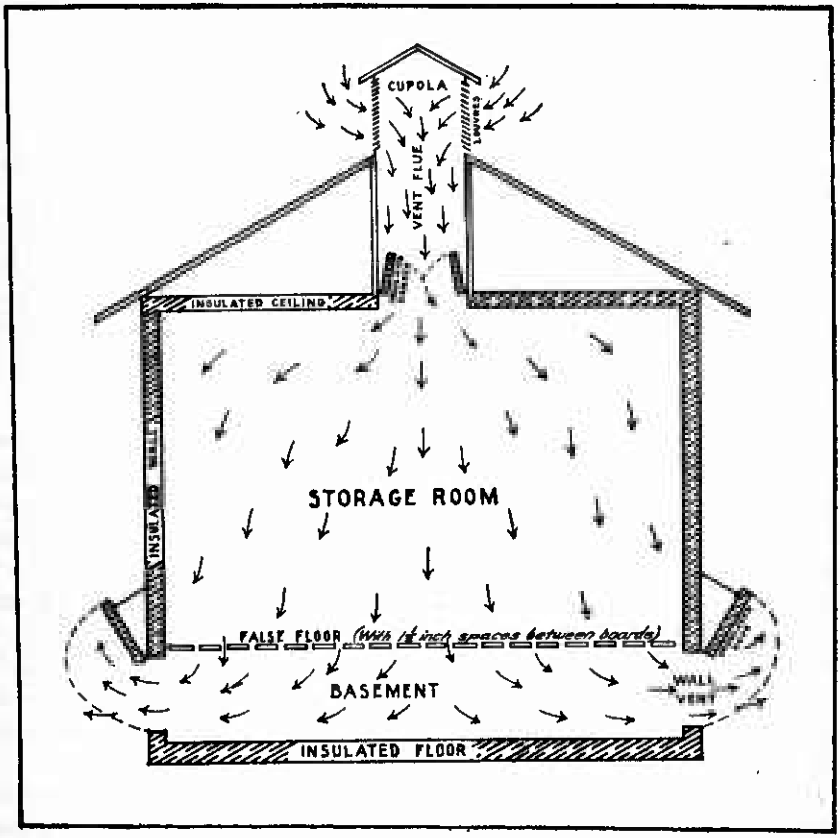

FIG. 3.—Cross section of a common storage house, with vent doors and dampers open, showing how air circulates when the temperature of the air outside the house is higher than the temperature of the product stored in the storage room.

accomplished at night, but the fruit will lose its keeping quality more rapidly than if held at a uniform, even though somewhat high, temperature.

The most careful attention to the proper closing and opening of ventilators is absolutely essential. No other factor of management is of greater importance in determining the efficiency of an air-cooled storage house. The openings at the ends will be of great assistance in facilitating rapid cooling and the maintenance of the desired storage temperatures.

If the house has not been provided with ample intake vents, the basement doors and those nearest the floor level may be left open on cool nights and made to assist greatly in securing low temperatures. Slatted doors, if necessary, can be provided to keep out intruders and can be so arranged as not to interfere with closing the insulated door; and, as has been noted, this must be done before the temperature of the outside air begins to rise with the heat of the day.

If the house is built with a basement or a half basement, the cooling of this compartment may be greatly facilitated by providing air intakes by means of large tile or cement pipes connecting the bottom of the basement with the lowest near-by outside depression from which water can not be drained into the house. The cold air which naturally collects in the depression will thus be permitted to flow into the storage compartment.

The air shafts for carrying off the warmer air ought to be at least 2 feet square and should be provided with a closing damper. One such shaft for every 20 feet in length should be sufficient. These shafts should be straight and should extend as high as practicable above the building.

FALSE FLOORS.

Where storage houses are entirely above ground or partly below ground, false floors will greatly aid in facilitating the free circulation of air and the rapid cooling of fruit. These floors may be made of 2 by 4 inch planks laid with open cracks about three-fourths of an inch wide or of much heavier planks a foot or more apart, with 1 by 4 inch strips of lumber crosswise of the planks, with a space of about 1½ inches between strips. (Fig. 4.) This false floor preferably should be laid just above the top of the lower openings. The outside insulated walls should extend below the false floor to the main floor, and the main floor should be equally well or better insulated than the outside walls.

If the false floor is 18 inches above the main floor there will be an open space 18 inches in depth underneath the entire storage space. This will permit the freest passage and circulation of air under and up through the fruit. Where such false floors are not used, the free

passage of air is very effectively obstructed by the fruit stacked in the storage room. The free movement of air is checked first by the packages nearest the openings and later by following various routes around the remainder of the packages in the house.

Where false floors are used, advantage may be taken of any strong wind that may be blowing during the ventilating period. If the openings on the leeward side are closed, the wind blowing in through those on the windward side will force a considerable current of cold air through the fruit. If the openings are left open on both sides when a fairly strong wind is blowing, the air may be carried in through the openings on one side and pass out through those on the opposite side without effecting much increased circulation upward inside the house.

FORCED CIRCULATION BY FANS.

The ventilation of the storage building and the cooling of the fruit may be assisted materially by means of power-driven fans. These are particularly helpful during the early part of the storage period, when low outside temperatures are of short duration and it is desirable to take the fullest advantage of these temperatures to hasten the cooling of the fruit. Fans for this purpose should be of good size and adapted to the rapid movement of large volumes of air. Fans of the propeller type are suitable, provided the air ducts are short and straight and of large area. Such a fan costs less and requires less power to drive than one of the centrifugal or blower type. It is not adapted, however, to driving air through long, small, or crooked ducts, as very slight resistance materially retards the delivery of air. Where false floors are provided, fans can be used to particularly good advantage.

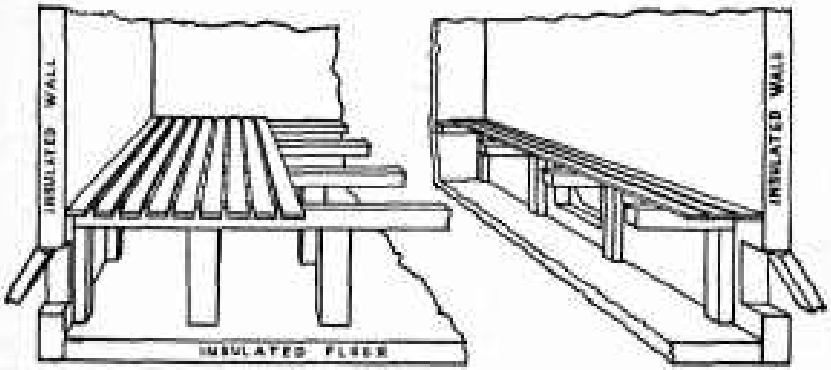

FIG. 4.—Sketch showing the arrangement of a false-floor structure for the common storage of apples, in order to allow the freest possible air circulation when the wall vents are open. The spaces between the floor boards should be about 1½ inches wide. The dimensions and spacing of the materials of the structure should be determined by the strength required to support the maximum load that may be stacked.

ARRANGEMENT OF BOXES AND BARRELS IN THE STORAGE ROOM.

Straight, uninterrupted 4-inch spaces between the rows of boxes and the use of 1-inch cleats between the boxes in a vertical stack will greatly aid in allowing the free circulation of air and effect much more rapid cooling of the apples.

In many houses the boxes of fruit are stacked solid, effectively preventing any circulation of cold air there might otherwise be. The boxes are also frequently stacked right up against the lower ventilators, making the free circulation of air impossible. The stacking of fruit and its arrangement so as not to prevent free circulation is of fundamental importance.

If the houses are not provided with false ventilated floors, the ventilation and cooling of their contents may be greatly facilitated by the proper arrangement of the boxes or barrels containing the fruit. First, each stack of containers, so far as possible, should be given the same advantages for rapid cooling as every other stack. This can be accomplished only by working out a plan of so piling the boxes or barrels that there shall be the freest possible circulation of air about each package. By placing 2 by 4's on edge on the floor and piling each stack of packages on these, a 4-inch air-circulation space will be provided under the load. It should be remembered that the cool air entering through the intake ventilators is the means depended upon for cooling, and the 2 by 4's should be laid with the object of distributing the air from the intakes under all parts of the load equally and as directly as possible. By placing the stacks of boxes 4 inches apart, air ducts will be provided between the stacks. By placing 1-inch strips between the layers of boxes and 2 by 4's between the layers of barrels, much better air circulation will be secured through the stacked fruit. If, in addition to this, the storage space is laid off in blocks, so as to leave passageways through the space in both directions, and these passageways are located opposite or in line with the intake ventilators, the cooling of the stored fruit will be greatly hastened. If different varieties and grades are placed in separate blocks, tho filling of orders at the time of shipment will be facilitated.

The more successful storage houses have the apples stored loose in field boxes. This permits much more rapid cooling, both because of the absence of wrapping paper and the greater facilities for the circulation of air around the fruit. The superior condition of unwrapped fruit stored in field boxes as compared with similar fruit wrapped, packed, and stored at the same time in the same house has been repeatedly demonstrated both experimentally and in commercial practice. This practice makes it possible to be certain that nothing but sound fruit is packed and shipped when the apples are removed from storage for grading and packing. If wrapped and

packed when stored, some repacking will oftentimes be necessary when the fruit is removed from storage for shipment.

RAPID COOLING FACILITATED BY THE EXPOSURE OF FRUIT TO THE OPEN AIR DURING THE NIGHT.

Rapid cooling may be greatly facilitated by leaving unpacked fruit in the open air during the night. The extent of the cooling that can be accomplished in this way is surprising, far exceeding that possible during a like period in a common storage house. In this way the temperature of the fruit may be reduced several degrees. The cooling which may be easily effected in this way is worthy of the most serious consideration. The fruit should always be placed under cover, however, before the heat of the day comes on. If it is to be stored unpacked, it can be placed directly in the storage room. If it is to be packed, the packing should be done promptly and rapidly so as to conserve as much of the night cooling as possible.

COOLING TO BEST ADVANTAGE.

The cooling of fruit in common storage is necessarily slower than in cold storage. Being slower, the length of time during which apples can be held in common storage successfully is necessarily shorter. In spite of this fact and the difficulties encountered in effecting rapid cooling and in maintaining uniformly low temperatures in common storage, much better results are possible. Cooling by ventilation is not automatic. To obtain the best results some one must make it his business to see that the ventilation with cold outside air is properly facilitated. The proper opening and closing of the ventilators can not be neglected, as commonly happens during the first part of the storage season, without serious loss of keeping quality. During the time when the strictest attention to facilitating ventilation is most necessary, little or no effort is made to regulate temperature conditions properly. The low outside temperatures which usually prevail at night are seldom utilized for cooling the fruit to an extent which is entirely practicable. Even in houses very inadequately insulated, apples can be cooled with a fair degree of promptness and held at reasonably favorable storage temperatures. This is possible, however, only where the apples themselves are properly handled and where the storage houses are intelligently managed.

The management of common storage houses, especially during the first part of the season, is concerned primarily with facilitating the free and abundant circulation of the coldest outside air through the house and the fruit. This means the opening and closing of vents in conformance with outside and inside air temperatures, the proper stacking of the fruit in the storage house, and the provision of false floors and fans for facilitating the circulation of air.

THE INSULATION OF A COMMON STORAGE HOUSE.

THE PURPOSE OF INSULATION.

In the storage of apples the temperature is of the utmost importance. The object in view is to maintain in the storage room a uniform low temperature, slightly above freezing. In a common storage building it is not likely that this condition can be even approximately realized during the harvesting period, as the average outdoor temperatures are reasonably certain to be much higher than the temperature desired in the storage room. During the winter months, on the other hand, in most districts where winter apples are grown, outdoor temperatures for at least a portion of the time will be considerably lower than the desired storage-room temperature. The chief purpose of the storage building then is to maintain the contents at a temperature different from that which prevails outside; therefore, the construction of the walls, ceiling, and floor must be such as to resist the passage of heat. Any material or method of construction which effectively hinders the passage of heat is termed insulation. The function of insulation in any storage building is to prevent as far as possible the outside heat from passing through the walls, ceiling, and floor into the storage room, and during extremely cold periods to retain sufficient heat within the building to prevent injury by freezing.

IMPORTANCE OF EFFECTIVE INSULATION.

Buildings intended for cold storage—that is, for artificial cooling—are usually well insulated, since inadequate insulation means directly increased cost for refrigeration. The importance of sufficient insulation in common storage buildings ordinarily is not fully realized. The necessity for the prompt cooling of stored fruit has already been pointed out. In common storage, where ventilation with cool outside air is the only means of removing heat from the fruit, the cooling is necessarily slow, owing to the slow circulation and the insufficiently low temperature of the ventilating air current. This is true even in a well-insulated building. In one that is poorly insulated, considerable leakage of heat into the building takes place during the warmer portion of the day, tending to offset in part the cooling accomplished by ventilation during the cooler portion, which results in a higher storage temperature and more delay in the cooling of the fruit than in a well-insulated building. With poor insulation it is impossible until cold weather sets in to maintain the temperature either as low or as uniform as is desirable. In extremely cold weather a poor insulation will result in the freezing of stored fruit where a good insulation would prevent any damage by freezing. Insufficient insulation is responsible for the loss of thousands of dollars through the freezing

of apples in common storage. This loss is entirely preventable by better insulation. While the cost of insulation comparable with that commonly used in cold storage warehouses may seem rather high, the conditions of intermittent and inadequate cooling by ventilation in common storage buildings really call for an insulation at least as good as or even better than that used for cold storage buildings. The greater permanency of the investment and the possibility of maintaining much more satisfactory conditions are factors worthy of serious consideration.

KINDS OF INSULATION.

Many of the common storage houses have practically no insulation except that provided in the form of hollow walls or so-called dead-air spaces. In others, the walls are filled with sawdust or mill shavings. Comparatively few are provided with commercial cork or mineral-wool insulation, such as is ordinarily used for cold storage buildings.

HOLLOW WALLS OR AIR SPACES.

Hollow walls or double walls, with so-called dead-air spaces between or within the walls, do not form an effective insulation unless the air spaces are broken up at frequent intervals. In some houses these air spaces extend without interruption from top to bottom. In reality, such spaces are not dead-air spaces, as the air in them is in constant circulation if there is any considerable difference in temperature on either side of the wall. The inclosed air lying against the warmer side of the air space becomes heated and rises, while that in contact with the colder side falls. A circulation is thus set up within the air space that has the effect of carrying the heat across from the warmer to the colder side of the wall, which is just what the air space is intended to prevent. To make an air-space construction really effective, great care must be exercised to have the spaces as small as possible. The smaller the spaces the less the tendency to circulation of the air within them. The expense of subdividing wall spaces into sufficiently small and tight air cells is so great as to render a really effective insulation of this kind impracticable.

SAWDUST AND MILL SHAVINGS.

A common and very practical method of insulation consists in filling wall spaces with loose material of such a nature that when packed tightly it will form a multitude of small air spaces or cells, these spaces being so small that the tendency to air circulation in the same is negligible. Among the materials suitable for this purpose are ground or granulated cork, mineral or rock wool, mill

shavings, and sawdust. Hay, straw, chaff, dead leaves, etc., are sometimes used, but are less effective and liable to rot and settle after being placed in the walls.

Sawdust is used to some extent, as it usually can be easily obtained, but there are several objections to its use. When obtainable in quantity it is often from green or partially seasoned wood, and hence contains considerable moisture in the form of sap. If placed in the walls in this condition it will heat and rot and finally settle, leaving open spaces in the wall, reducing the effectiveness of the insulation and ultimately causing the rotting of the woodwork of the walls themselves. Mill shavings are usually obtainable at low cost and in some respects make a more satisfactory insulating material than sawdust. Neither mill shavings nor sawdust should be used unless in a thoroughly dry condition, and they should be firmly packed and surrounded by waterproof paper. Ordinary building paper is not waterproof and should not be used. Either sawdust or mill shavings, if perfectly dry when placed in the wall and protected against the absorption of moisture by completely surrounding them with waterproof paper, make an economical and satisfactory insulation for common storage houses.

CORK AND MINERAL WOOL.

Mineral wool in loose form is usually somewhat expensive as a filling material, but it makes an effective insulation. Precautions are necessary in handling this material, as the glasslike shreds are sometimes rigid enough to penetrate the skin of the hands and cause sores, while the dust from the wool is harmful to the lungs. Mineral wool has the advantage of being a fireproof and vermin-proof material. Like sawdust and shavings, it requires thorough protection against moisture. Granulated or ground cork makes an excellent and very effective insulation. The principal objection to its use in the Northwest is its cost. It also requires to be protected against the absorption of moisture.

Cork or mineral wool in board or slab form is the material generally used for insulation in commercial cold storage houses. This is the most expensive and also the most efficient kind of insulating material. The slabs of insulation are attached with either Portland or asphaltum cement directly to the interior walls of the storage rooms, the cement serving both to support and waterproof the insulating material.

New insulating materials are constantly appearing in the market. These should be regarded as of value only when satisfactory tests show them to be comparable to cork or mineral wool.

DOORS AND WINDOWS.

The doors opening into the storage room should have an insulation equal to that in walls, ceilings, and floors and should fit tightly and snugly, so as to permit no leakage of warm air through them. It is also advisable to provide an entry or hallway sufficiently large to permit the closing of the outer door prior to the opening of the door leading into the storage room while trucking fruit into the storage house. There should be as few windows as possible, and where electric lights are to be had windows can well be left out entirely. Where windows are necessary there should be at least two (preferably three) thicknesses of glass.

THE USES AND ABUSES OF STORAGE HOUSES.

A common storage house is primarily intended for the storage of fruit. Even where utilized for this purpose only and efficiently managed, it is oftentimes extremely difficult to effect the necessary cooling. Where these houses are used for packing and sorting purposes during the beginning of the storage season, the maintenance of satisfactory storage conditions during such periods is out of the question. Common storage houses are very often used for packing during the harvesting season, thereby nullifying the very purpose of such houses. It is imperative that a separate space be provided for packing and storing box shooks. The packing of the fruit should be done in another building. The storage room should be opened only for taking in or removing fruit and for ascertaining the inside temperature conditions.